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Hydrokinetic energy conversion systems: A technology status review

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ABSTRACT

The growing demand for electrical energy is one of the most important subjects today. Decreasing amount and environmental effect of fossil fuels does not seem to surmount this challenge. Renewable energies give a good perspective to be an alternative to fossil and nuclear-fueled power plants, in order to meet growing demand for electrical energy. Hydropower is well known in this category. Hydrokinetic energy technologies are relatively new than other hydropower systems. In this work has been investigated these kinds of hydrokinetic energy, and given some detailed information about current base of hydrokinetic. It has tried to give some knowledge in order to familiarize with the hydrokinetic turbine and generator. The selection information of a suitable turbine has been mentioned.

Contents

1. Introduction

Rapidly increasing world population, developing and growing demands of humankind and consumptions made by the society raises the requirement of energy with each passing day [1]. Weighted amount of energy used today is being met from fossil fuels, which are limited and are decreasing day by day [2]. The most important concerns today are ensuring sustainable existence of natural life and leaving a livable and unpolluted environment for next generations, which is accepted by all interested groups. As known, the usage of fossil fuels causes environmental pollution, greenhouse effect and CO_2 emissions [3]. Therefore the reducing reserves and delimiting the use of fossil fuels seems an urgent necessity. For executing this, it is vital to use other alternative energy sources [4]. An ideal energy source should be renewable and should have minimal negative effect on environment [5]. Renewable energy sources are essential in order to provide a

Abbreviations: *K*, performance coefficient; ρ, density of water (kg/m^3); *A*, cross-sectional area of the rotor (m^2); *V*, free stream velocity of water (m/s); *P*, power produced (W); *D*, swept diameter of rotor (m); *H*, height of the rotor.

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sustainable power production in the future [6]. Under renewable energies hydro, wind, photovoltaic (solar), biomass, geothermal energies can be enumerated [7]. Hydro and windpower seem to be the optimum choice among the renewables available today.

There are five main types of marine and hydrokinetic energy technologies: oceanwave, tidal stream, river hydrokinetic, ocean current and ocean thermal [8]. Flow is an essential concept of waterpower. There are mainly two methods of extracting energy from water flow. As given above, the classical method is to make a dam for constitution of a static head. The other method is extracting energy from different water currents such as tidal, ocean, river and irrigation canals [9]. Gorban et al. [10] explain that the principal difference between exploiting high-head and free flow turbines is that the latter needs large flow openings to capture as much water masses as possible with low velocities and pressure. Kinetic energy potential of rivers, based on the distribution of water velocities rather than stream flows, indicates higher values [11]. A river current energy conversion system can be described as an energy converter which harnesses the kinetic energy of river streams [12]. The possibility of meeting our increasing energy demands with conventional hydropower seems very limited. The energy in flowing water current seems a good choice of renewables. Water provides the renewable energy option with a possibility of a continuous supply because this kind of energy does not need the storage [13]. This emerging kind of renewable energy is being considered as an unusual technology, which shows a good application possibility of using river and marine currents. The kinetic energy of water current is converted to mechanical power which rotates a generator to produce the electricity. The working principle of hydropower from water currents can be seen in Fig. 1. The working of a water current turbine is similar to that of a wind turbine. This concept is not new, and was investigated by different researchers since 1979 [14]. The studies in the beginning phase were on small scale. After 1990 a new idea of utilization of water current turbine (WCT) for large scale has been emerged [15].

It is known, that the waterpower is the cheapest renewable energy source. Conventional hydroelectric generation by means of dams is used in order to benefit from renewable energies. This system of conventional hydropower is not sufficient to meet our increasing energy demands. Furthermore, there are a variety of environmental concerns about classical hydropower. The creation of a water dam causes some big changes in nature. The most important of them is submerging of generous agricultural lands. First class agricultural land is very limited in our world. Additionally planting of biomass vegetation decreases the total land suitable for cultivation of foodstuffs, which was the main reason for the increasing of foods in recent years [16–21].

This study has mentioned the possible usage of hydrokinetic energy to produce renewable electricity. The development of the hydrokinetic water turbine, which is one of the main topics for national energy agencies, has been strived for very intensively by different enterprises. It has tried to give a categorization of the hydrokinetic turbine, an overview and differences from various sides. This paper introduces all kind of water current turbines. Beyond that a classification of different kind have been made. In addition to that it has tried to give a future concept about suitable turbines for river and tidal currents. In the next section a basic calculation of extracting energy from the water currents turbine will be given.

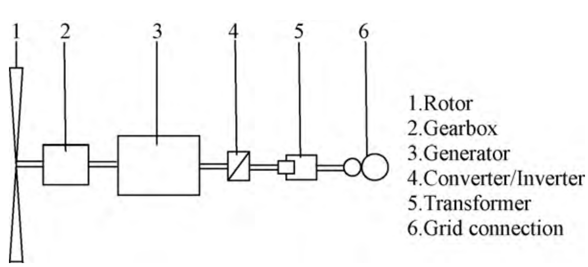

Fig. 1. Principle scheme of water current turbine systems.

2. World energy outlook and hydrokinetic usage

Economic growth and increasing human demands are among the most important factors for growing world energy consumption [22]. The projection of the world energy consumption for 2030 is shown in Fig. 2. The expectation of energy generation by different fuels is shown in Fig. 3, and the development until 2020 is given in Fig. 4. Due to the increasing oil and natural gas prices and the decreasing amount of world oil reserves, the usage of alternative energy sources is unavoidable and preferable nowadays. The estimation of world renewable energy generation in 2010 is represented in Fig. 5. The usage of renewable energy is strongly expected to rise in next few decades, and the projection for 2020 is given in Fig. 6. Hydrokinetic energy capacity forecast is shown in Fig. 7. The future projection of hydrokinetic energy production by different technologies is given in Fig. 8 [22].

All interested parties consent today to use of renewable energies for covering the increasing energy deficit. Therefore generating electricity from renewables is now one of the most strived for investigations. The oceans and the rivers represent a vast untouched resource for renewable energy generation. According to the report from Pike Research, Ocean energy industry can provide a significant new source of electricity, reaching up to 200 GW of installed generation capacity by 2025. More than 300 hydrokinetic projects are already in the pipeline around the world [8].

Some countries and unions such as USA (see Table 1) and Europe are thinking to impose carbon regulations and marine renewable energy targets. In keeping with these targets, hydrokinetic energy production from the ocean and the rivers may grow by 22 GW in the next five years [8]. On the other hand, Energy Technologies Institute reported that marine energy could supply up to 2 GW of UK energy demand by 2020 [23]. There are two types of hydrokinetic power, current-based and wave-based. In our work will investigate the current-based type. Water currents can be divided into four categories shown below [24]:

- River currents,
- Tidal currents,
- Ocean currents,
- Irrigation and other manmade canals.

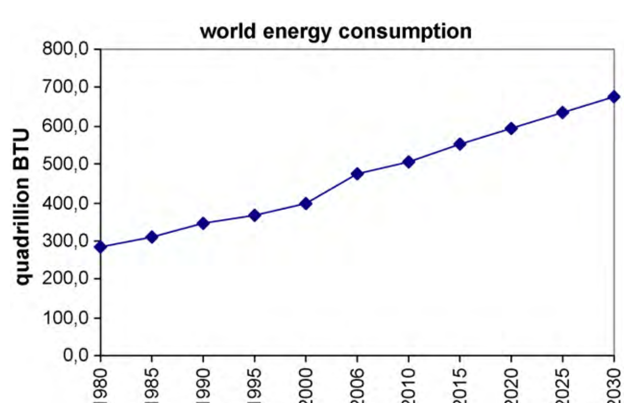

Fig. 2. World energy consumption.

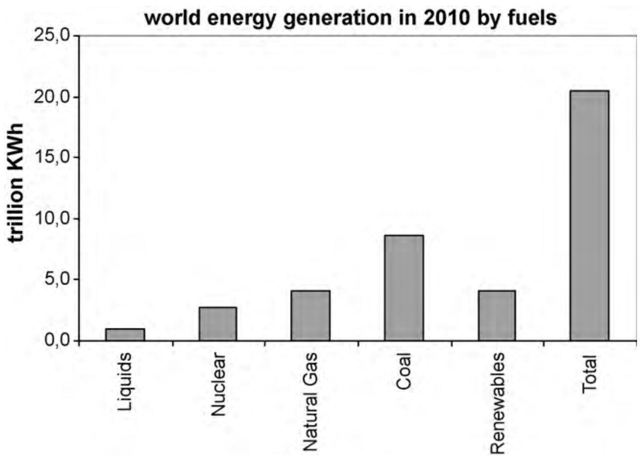

Fig. 3. World energy generation in 2010 by different fuels.

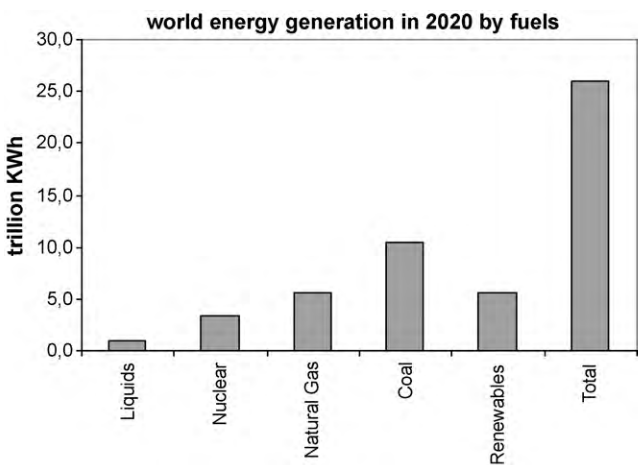

Fig. 4. World energy generation in 2020 by different fuels.

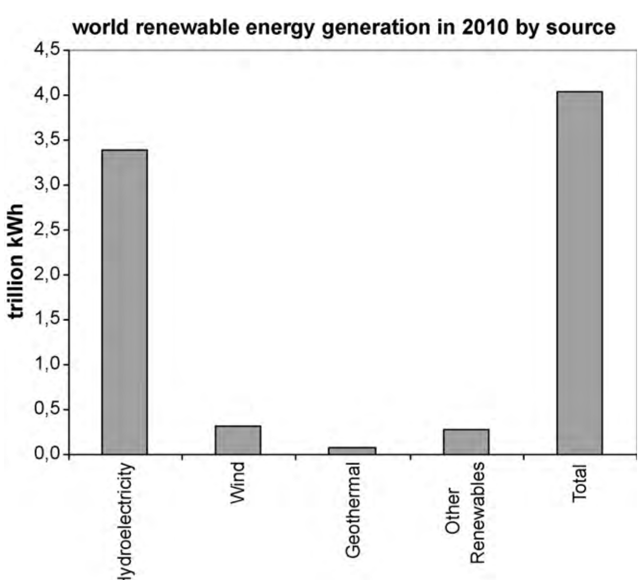

Fig. 5. World renewable energy generation in 2010 by source.

This new generation of hydropowers (current-based and wave-based) gives a possibility of generating electricity from the movements of water which shows zero environmental affect. The power expected from tidal currents could be approximately

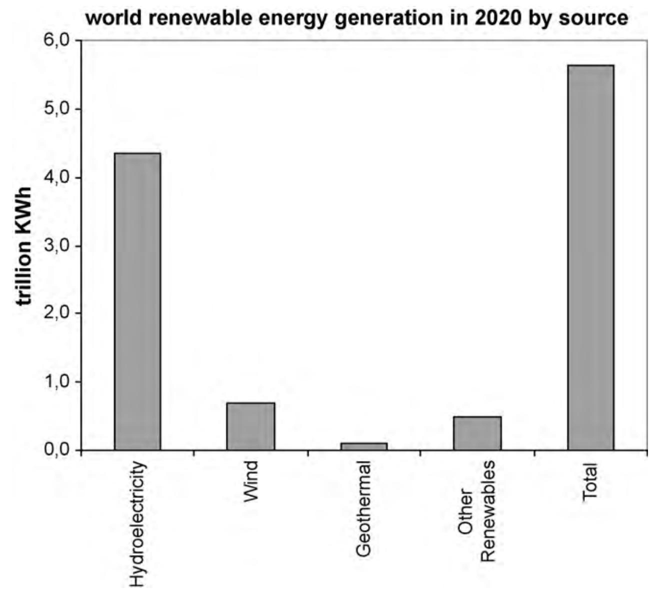

Fig. 6. World renewable energy generation in 2020 by source.

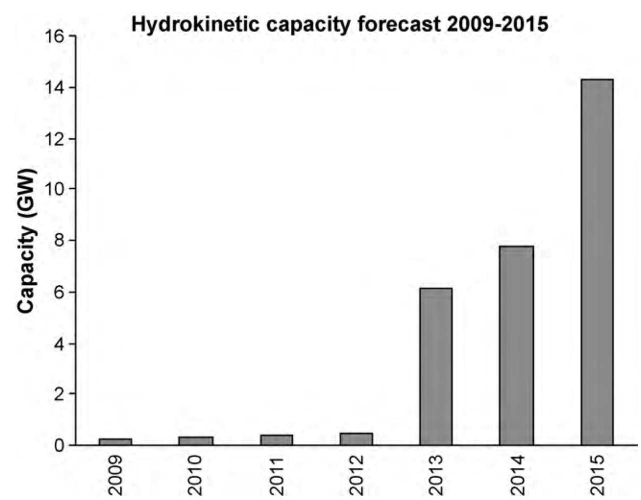

Fig. 7. Hydrokinetic energy capacity forecast 2009–2015.

100 GW world-wide [25]. Some benefits of current-based hydrokinetic energy are: being predictable, forecastable, environmentally friendly, water-life friendly, having minimal visual impact, having no emission and no noise [26]. With hydrokinetic turbines 12 million GW/h can be produced in the main river [27]. In USA the tidal power in ocean currents has been estimated about 5000 GW [28]. The river current energy estimated by Hall et al. is 3400 MW [29].

3. Calculation concept of hydrokinetic water power

The valid equation of water current turbine is analogous to that of wind power [30]. The power removed from a stream of water current is:

$$P = K \times \frac{1}{2} \times \rho \times A \times V^3 \qquad (1)$$

The area of the Darrieus turbine and others is equal to diameter times the height.

$$A = H \times D \qquad (2)$$

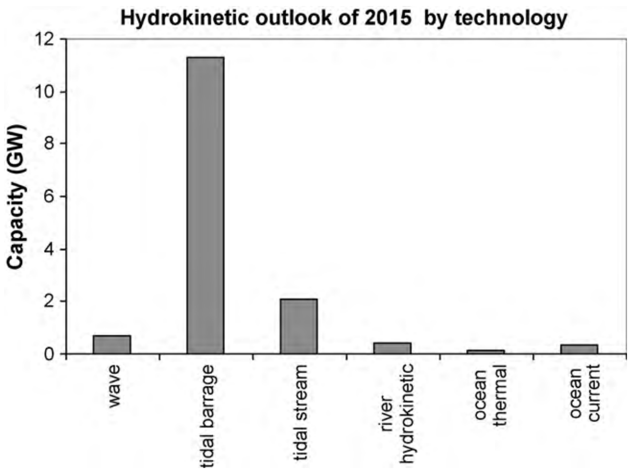

Fig. 8. Hydrokinetic energy Outlook of 2015 by different technology.

For axial flow turbines the area *A* can be taken as swept area of the rotor.

$$A = \frac{1}{2}\pi D^2 \quad (3)$$

Water current turbines extract energy from the fluid by reducing flow velocity. There is a theoretical limit to the percentage of kinetic energy that can be removed from the flowing fluid to the kinetic energy maximum available in fluid. This limit is known as Betz limit. Betz limit is 59.3% for a single and open actuator disc. Power coefficient K is a measure of the fluid dynamic efficiency of the turbine and differs depending on manufacturer [6]. It became a common practice to use this limit for estimating the maximum efficiency of such turbines [9]. Performance coefficient takes different factors into account. Each turbine has a different maximum value of *K* which indicates the efficiency level of the turbine. It is important to remember that the Betz limit is valid open free flow turbine. The efficiency can be higher for ducted WCT, ρ is the density of the fluid which can be taken for river water 1000 and 1025 kg/m^3 for seawater. Actually the salinity and temperature variation of seawater causes the fluctuation of the density between 1020 and 1030 kg/m^3 [31].

Ocean and river current speed is generally lower than wind speed. Such turbines are designed for water velocity of 2–4 m/s Wind turbines are calculated for optimum wind speed of 11–13 m/s [30]. Water is 835 times denser than wind. In ocean currents it has been estimated to be about 5000 GW [32]. Consider of all these above-mentioned facts, water current has a significantly higher energy capacity than the wind [33]. Fraenkel [34] gives similar comparison between wind and marine current turbines. Table 2 shows the capacity of marine turbines [34]. Fig. 9 also shows a hydrokinetic energy converter system [12].

4. Kinds of hydrokinetic turbines

The types of WCT employed can be characterised by their rotational axis orientation with regard to the water flow direction [35]. The classification of hydrokinetic turbines can be made basically as horizontal axis and vertical axis. The horizontal axis turbines can be separated into two groups. The rotational axis of the first one is parallel to the water stream direction. The rotational axis of the other is perpendicular to the water stream direction. Water wheels or cross-flow turbines can be classified as perpendicular horizontal axis turbines, about which no further information will be given because the technology is old and known well. Similar and other classifications of the hydrokinetic turbines have been given by different authors. The scope of this section is restricted in axial and vertical turbines. Additionally existing and developing products from different manufacturer have been given. Some kinds of WCT can be used as horizontal and vertical. They are introduced then, where they are used often. Images of different hydrokinetic turbines are given in Fig. 10.

4.1. Horizontal axis turbine

As mentioned above in this section, information about parallel axis turbines which can be named as axial turbines will be given. The rotational axis of an axial turbine is parallel to the water current direction. We can see the similar axial turbine by wind

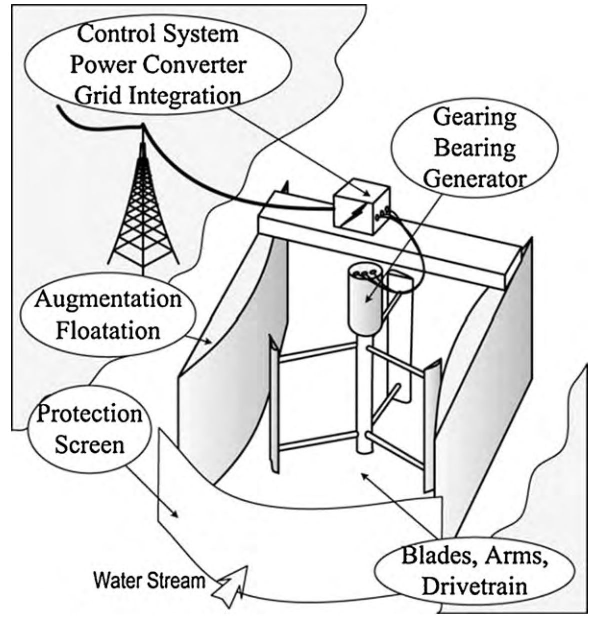

Fig. 9. Outline of a hydrokinetic energy converter system [12].

Table 2
Capacity of marine current turbines by different velocities.

Rotor diameter	Velocity of 2 m/s	Velocity of 3 m/s	Velocity of 4 m/s
5	32.5 kW	105 kW	250 kW
10	130 kW	420 kW	1000 kW
15	292.5 kW	945 kW	2250 kW

Table 1
Estimated waterpower technology capacity gains in USA (MW) [15].

Waterpower technology class	2006	2007	2008	2009	2010	Cumulative
Capacity gains at existing hydropower facilities	76	90	75	75	59	375
New hydro at existing dams	–	–	–	–	25	25
Small and low power hydro	–	–	–	50	75	125
Hydrokinetic	–	0.2	–	4.8	110	115
Ocean wave energy	–	–	3	1	80	84
Yearly capacity gain	76	90.2	78	131	395	724

Fig. 10. Images of hydrokinetic turbines.

farmes. Axial flow turbine can be usually constructed as two-, three- or multi-blade. The structure can be opened or ducted.

4.1.1. Two-blade turbine

Seaflow can be seen as a first project in the literature [36]. Seaflow is supported by EC to develop a commercially sized marine current turbine (MCT). The turbine has a rotor diameter of 11 m and is two-bladed. We can imagine it as a wind turbine but submerged underwater. The turbine used by this project gives 300 kW. This project is developed for tidal energy usage. But its application is possible for all other marine currents. Marine Current Turbines Limited is the manufacturer this kind of two-blade turbine. Hereby is used the kinetic energy in tidal currents Generating power from tidal currents is a relatively new approach. With this project small scale generating systems have been demonstrated. Several large scale commercial systems are in development and will be finished soon [36].

MCT can be called submarine watermills. This system is very similar to a windmill. MCTs are being installed in the sea at places with high tidal current velocities, to take out energy from the huge

volumes of flowing water. These flows have the major advantage of being a predictable energy resource unlike wind and wave energy [32]. Tidal current turbines are not weather-depended. This technology of Marine Current Turbines Limited is under development and plans to achieve 20 m rotor diameter. This technology is cost competitive. Energy capacity of MCT is 4–15 times higher than a good windmill. Marine currents are known as a huge and untapped energy resource and seem to be capable of meeting our future energy needs.

Every off-shore energy technology has a challenge of grid connections. The installation cost of off-shore cables is very expensive. The reducing of grid connection can be overcomed with installing large scale water current turbines farm. It seems to be necessary, that this system is to be connected with existing and stable electrical network, because the usage of permanent magnet generator causes changes in the output voltage by water velocity fluctuation [37]. On the other hand, for the selection of application-area the current velocity can be considered. It shall be more than 2 m/s. Availability of the stable water velocity seems an advantage. Such a conditions can be found easily on country sharps (headland), marine reserves between islands and straits. [38].

4.1.2. Three-blade turbine

The three-blade system has been manufactured by Verdant Power. The complete system is assembled underwater to generate electricity from water current of tidal and river system. The system is similar to three-blade wind turbine. The three-blade axial flow turbine is designed to give high efficiency over a large range of water speed. The turbine rotates slowly approximately 35 rpm by the natural currents of tidal and river [39]. Two river projects have been applied by Verdant Power for river application. RITE Project and CORE Project. RITE Project has been realized in New York East River. Here a new turbine of 5 m diameter has been installed. This turbine gives a capacity of 35 kW and rotates 32 rpm [40]. This company plans to expand this project to 2–4 MW CORE Project has been planned to realize in two phases and will be applied in the St Lawrence River in Ontario Canada. First is the demonstration phase continuing from 2007 to 2010. Here 5 m rotor turbine will be used. In the second phase the capacity will be expanded to 15 MW. This project will weightily be funded by the Ontario Ministry of Research and Innovation [39–41].

Hammerfest Strom too has three-blade turbine system. A 300 kW prototype of a tidal power station was installed in Nordern Norwey in 2003. The system has been working for more than 4 years. The company explains that no problem has been registered [42].

4.1.3. Multi-blade turbines

In this category there are some manufacturers. Here information about the manufacturer and their system will be given.

Lunar energy offers a system which uses tidal current to produce electricity. The name of their system is Rotate Tidal Turbine (RTT). RTT is a fully submerged ducted turbine with the power conversion system inserted in a slot in the duct as a cassette [43]. The rotor has 11.5 m diameter and has a six-bladed structure. The usage of bi-directional ducted structure, which has a ventury shape, allows increasing the energy that can be captured by the turbine. This system is designed to give 1 MW power. RTT is a bi-directional axial turbine housed in a symmetrical ventury duct. This system has a gravity foundation, which facilitates the assembling on the seabed places. The ventury shaped duct straightens the water current flow and causes to take more power from the turbine system compared with the open system [44]. The best usage of RTT system can be made in areas where the water current velocity is predictable and has high values. This system is designed for tidal currents and can be assembled at a depth, where it will not have any influence on shipping [43–45].

UEK (Underwater Electric Kit) has dual hydroturbine system. It is suitable to operate in stand alone and with grid connection usage. The system of UEK can be installed in free flow manner or at the bottom of the river. The dual UEK system is designed for stream velocities from 2 to 4 m/s for optimum usage. The turbine has a diameter of 3.3 m. This dual system gives approximately 75 kW at 2 m/s velocity [46]. This company has two projects. One is in Yukon river in Alaska, where 100 kw System will be installed. The other is Indian river tidal power plant which will consist of 25 twin UEK system [47]. The company UEK shows that the new technologies such as UEK's low impact hydrokinetic turbines would provide the vast majority of installed renewable generating capacity. As an advantage, this system can be installed beneath the water's surface [48].

Free Flow Power Technology (FFPT) has an integrated turbine generator system, which is called Smar Turbine Generator. The system has a ducted structure. This company is currently developing a project in the Mississippi River Basin. They planned 100 hydrokinetic sites on Mississippi, Ohio and Missouri Rivers [49]. Smar Turbine Generator is a permanent magnet, direct-drive generator. The system has rare and front diffusers. The rotor is designed to operate in a wide range of flow velocities. This company is currently producing a 3 m diameter version of the Smar Turbine Generator. Another size of 1.4 m diameter was tested at labor conditions and is being tested in various environments. It is expected that all the tests needed for this range shall be finished in a year [50].

Open-hydro designs and manufactures marine turbines to generate electricity from tidal streams. The name of this system is Open-Center Turbine, which is designed to be installed directly on the seabed [51]. The center of the rotor is open. The name comes from it. This company says that their system is robust and simple. The system has slow-moving rotor and lubricant-free operation that minimises the risk of marine life [50]. It is declared by the company, that the first turbine of this company was built in October 2007 [52]. Open centered turbine of 3 m diameter generates 15.5 kW of electricity [53].

Atlantis Resources Corporation is developing two families of sub-sea turbines. The names of the turbines are Nereus and Solon. Nereus is a shallow water turbine, which has been tested and grid connected in Australia. Solon is a deep water turbine. The company means that Salon was convenient for installation in some of the latest flowing currents in the world [54]. On the other hand, The University of Southhampton is trying to design their own tidal generator since 2006. It is expected becoming commercially available by 2011. The system has a ducted structure with multi-blade [55].

4.2. Vertical axis turbine

If the rotational axis of turbine rotor is perpendicular to the water surface, such turbines are named vertical; typical examples of vertical axis are Darrieus, Helical turbine, etc. Alternative Hydro Solution Ltd says that the Darrieus turbine is the best choice for small and medium river sites. They explain that their system is able to have greater diameter than depth which enables more area to be swept in a shallow stream and therefore more power production per turbine. The vertical shaft can ensure that the generator and bearings are above water [56]. The company means, that their turbine was constructed of high quality and durable material. The blade and the arms are made from Aluminium 6063T5. Their turbines are available in four different diameters: 1.25, 1.5, 2 and 3 m [55]. Alternative Hydro Solution has a wide range of sizes. The smallest turbine has a diameter of 1.25 and the height of 0.5 m. [57].

Helical turbine has a same working principle as Darriues turbine. Gorlov helical turbine consists of two or three-blade with helical form welded between two discs. Gorban et al. [10] mean that the helical turbine has some advantages compared with classical Darrieus as follows. The helical turbine would allow a large mass of slow water to flow through, capture its kinetic energy, and utilizes a very simple rotor, which would be a major cause of its low cost. Gorlov helical turbine rotates faster, its direction of rotation is independent of water flow direction. It can be assembled vertically horizontally and in cross-flow [58]. It is declared that the maximum efficiency is equal to 0.30 [10]. The system is applicable for river, tidal and any manmade canals [59].

Blue energy technology produces the Davis Hydro Turbine, which is a similar to H-Darriues. The system has four fixed hydrofoil blades which are connected to a shaft, that drives a variable speed electrical generator [60]. On the other hand, the HydroVolts is a Flipwing turbine which are designed and developed by some engineering student at the University of Washington. The turbine can be constructed with 3, 4, 5 or 6 blades. The turbine blades spin with the water current, generating their force from drag [61].

5. Generator, speed increaser and control mechanism

The term generator is used in this paper for the equipment, which converts the mechanical energy produced by hydrokinetic turbine to electricity. Generator can generally give direct current or alternating current. DC cannot be transmitted across the long distances. Their usage is restricted in very nearly environment from utilization place. AC can be transferred easily over long distances. Additionally high voltage AC has good transmitting efficiency. AC is excellently suitable for providing electricity in remote areas [62].

The question, how the end users wish the renewable energy, must be clearly answered, whether stand alone system or grid connected. Stand alone system can be divided in two categories, limited usage in an household or fully supply for all equipment. Limited usage can include the lighting, heating and battery charging system. In that case DC generator can be used for producing electricity for limited usage. After battery storage with choosing a suitable inverter, it is possible to supply alternating current for 110 or 220 V for other equipment such as washing machine, etc. [62–65].

For grid-connected usage AC shall be generated. For this purpose, synchronous or asynchronous generator can be chosen. The synchronous generator can be used only for big size hydroelectric system or for diesel engine. Induction generator and permanent magnet generator can be used for producing of AC. Induction generator are robust and very reliable, therefore they offer a good application possibility for remote areas [56,62].

The number of poles of a generator gives the rotational speed. Small size induction generator has two or four poles. Four poles generator rotates 1500 rpm approximately. After selecting the generator with rotational speed and identifying the turbine rotational speed, next question is choosing a speed increaser system such as belt-pulley or gearbox. The rotational speed of hydrokinetic turbines varies from 30 to 100 rpm. Two-stage speed increaser is needed then for these rates. Increasing rates and the transmitted moments influence the choice of gearboxes belt-pulley [9,12,25].

Most of the early hydroelectric systems produced DC, but nowadays three phase AC generators are usually selected in normal practice. Generators need an excitation system for starting the production of electricity. This can be realized with the system of self-excitation or grid-dependent excitation. Synchronous generator is equipped with a DC and they can produce electricity independent of grid [63]. Additionally this system has a voltage regulator to control the output voltage. Asynchronous generator is very similar to squirrel cage induction motor. They do not have any possibility of voltage regulation, therefore a stationary water regime is required in all cases. The running speed of turbine shaft influences directly the system frequency. For induction generator, self-excitation or grid-dependent system is possible.

The selection of generator is dependent on the question, how big or small is the power of the system relatively to the other generators of the grid. Most cases are confronted that the power of hydrokinetic system is very small as compared to other generator connected to the grid. Then the following control mechanisms for induction generator are possible such as [64]:

- Induction generator connected directly to the grid. This is the cheapest system, in which the turbine must run at nearly constant speed. A stationary water regime is a must for this system.
- Induction generator with multi-winding of motor to balance of speed fluctuation of the turbine.
- Variable speed generator can be chosen. The output of VSG is rectified to DC. Then the defined AC is produced by suitable DC–AC inverter.
- Double-fed induction generator can be used. Active change of the current and phase in the generator's rotor constitutes the increasing of the effective slip on IG.

6. Environmental impacts

The production of electricity by hydrokinetic turbines does not have harmful air emission, such as greenhouse gases. But, the technology is in the beginning phases. Therefore, further research is necessary to determine, what other types of environmental effects may occur from tapping the energy in water currents. It seems that, underwater assembled and rotated devices can causes some changes and impact on their environment given as following [9,12,57,62]:

- The effects on the habitats of benthic animals and plants like oysters, clams and sea grass.
- A big size array of hydrokinetic conversion system can create significant noises which can influences marine and river life.
- The devices can hinder the movement of aquatic animals.
- The system and manmade canals can alter hydrologic and sediment regimes
- Other users of the marines such as fisherman, shipping vessel operators, boat maker and coastal citizen groups can show some concerns and troubles.

These impacts can be minimized by appropriate site selection, project design and proper preventive measures. Experience with pilot projects can be used for future investments [65].

7. Results and discussions

The complete energy conversion system requires rotational speed increaser such as gear box or belt-pulley and generator of different suitable kinds and control system beyond the turbines.

The selection of generator depends on water regimes. Providing stationary water regimes can make it possible to choose a simple induction generator. For achieving this goal an open water canal such as irrigation for vertical axis turbines can be set up adjacent or near to the river bed. The axial hydrokinetic turbines can be installed better in closed water canal which has ventury mechanism before the turbine unit to supply more mass of water

Table 3
Technological comparisons of the renewable electricity [24].

Renewable energy source	Energy density	Capacity factor (%)	Emissions	Visual impact	Potential sites	Remote power cost (¢/kWh)	Utility power cost (¢/kWh)
Hydropower or hydrokinetic	High	95–100	None	Minimal	Unlimited	4–7	4–7
Fossil fuel	Very high	50–90	CO_2, SO_2, NO_x	Very high	Extensive	30–55	4–8
Onshore wind	Low	25–35	None	Moderate	Limited	9–10	4–8
Off-shore wind	Moderate	25–35	None	Low	Limited in USA, Moderate in EU	16	6–9
Solar	Low	10–20	None	From unobtrusive to high	Limited for high energy density, Extensive for low to moderate density	25–50	10–25

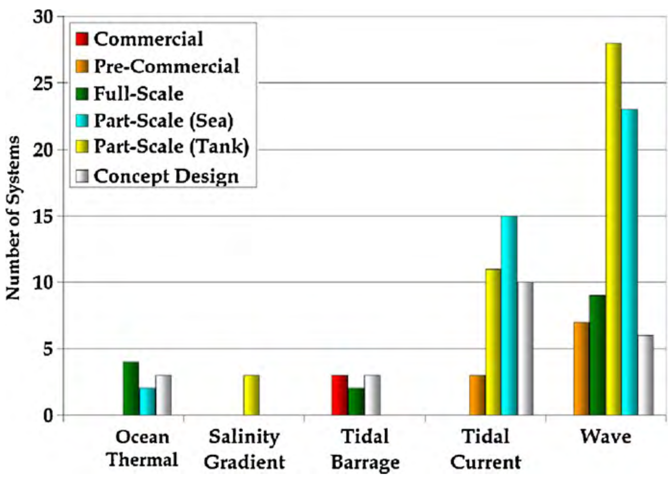

Fig. 11. Technology maturity of various ocean energy conversion systems.

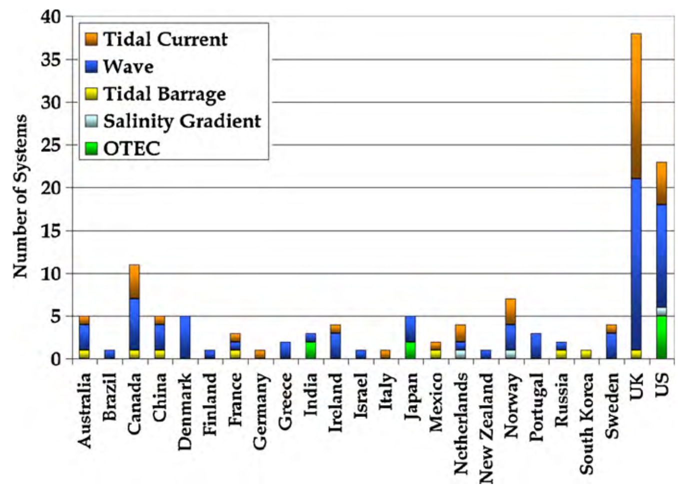

Fig. 12. Ocean energy-related research, demonstration and commercial activities in 2007.

and velocity. As it is seen in Eq. (1) the power extracted from the water stream increases with stream velocity in third exponent. The complete hydrokinetic energy conversion system consists of four different components or works. The classification of these can be made as follows: turbine unit, speed increaser, generator-control device and assembling unit-water canal. All parts of the system, which have to show a good conformity with one another, have equally essential roles.

The cost of hydrokinetic electricity is strongly influenced of the power density of the stream and from the distance of transmission of electricity to reach the consumers. The mentioned system shall be simple, robust and price-competitive. River application allows the usage of small system. Ocean current application seems to develop big devices such windturbines, therefore ocean current system shall be good competitive with windfarmes. On the other side, the hydrokinetic energy conversion system may have some unwanted effect on environment such as damaging of sensitive marine and river environments, insecurity for fish and other aquatic species. Environmental concerns about water current generated electricity including routing of transmission lines and manmade canal have to be overcomed. Our civilisation already uses the water resources in a wide range. Subsequent to proper environmental and siting review, hydrokinetic energy can be embedded safely into the mixed using package of the water and currents. Marine currents energy conversion system indicates cost prices between 4.8 and 10.8 $/kWh, which can be decreased in next decade as much as in wind industry [60–65]. With proper support of project development and deployment, hydrokinetic electricity can become economically competitive with conventional fossil fuels and other renewables no longer available (Table 3) [24]. Fig. 11 shows technology maturity of various ocean energy conversion systems. Fig. 12 also shows the ocean energy-related research, demonstration and commercial activities in some countries over the world for 2007.

8. Conclusions

The river current and partially the tidal current hydrokinetic systems are at the beginning phases of their development. Some capacity information from manufacturer at different stream velocities has been given. Therefore making a decision about which product has better efficiency can be difficult. The vertical axis turbines usually need some exciting and starting mechanism. The trends of the usage of tidal currents grow day by day to the bigger capacity system. Therefore for harvesting of tidal currents axial turbine systems seem better suited. Here open or ducted system can be selected. The ducted turbine with diffuser and ventury system can give more power than the open type, but the first investment cost would be higher. It can be said each system has own advantages and disadvantages. The river current system indicates more restriction for usage because of the size of rivers. The use of hydrokinetic system in rivers can be realized in manmade canal similar to irrigation or after the dam-turbine outgoing point or if possible directly on the river bed. Vertical axis Darrieus, H-Darrieus or Helical turbine can be used for the cases, where the water flow rate is relatively limited. The selection of the most suitable one is a question with a versatile answer. But all kinds of hydrokinetic electricity systems offer a good and brilliant hope to meet our energy demands with clean, sustainable and renewable energy in all cases with the consideration of overcoming environmental concerns.

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